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PROCEEDINGS

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REDESIGN OF MAJOR AIRPORT TERMINALS

By Herbert H. Howell, M. ASCE

AIR TRANSPORT DIVISION

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AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS

REDESIGN OF MAJOR AIRPORT TERMINALS

By Herbert H. Howell,[1] M. ASCE

Synopsis

The development of electronic devices for all-weather flying will make it necessary to increase the capacity of many major airports. The trend will be toward the redevelopment of existing airports rather than the construction of new fields.

The requirements of an adequate design are discussed and illustrated by reference to a typical redesign as worked out for the Lambert-St. Louis Municipal Airport (St. Louis, Mo.). The advantages of the improved layout are described and related to the general problem of airport redesign.

Introduction

In the years following World War II, many great improvements in devices to aid in the navigation and landing of aircraft in inclement weather were developed. The program of the Civil Aeronautics Administration (CAA) in connection with this type of operation follows, as a guide, a report[2] that proposes certain criteria for a common system of aids to navigation. The CAA is working toward the early completion of the so-called Transition Period Common System of Air Traffic Control and Navigation. To re-evaluate the usefulness of the Common System, a special group, known as the Operational Policy Group, was appointed by the Air Coordinating Committee's Air Traffic Control and Navigation Panel. This group has completed its work and issued a report[3] that re-emphasizes the value and necessity of a common system. This report should be studied by all airport engineers.

The essential features of the Common System are: (*a*) very high frequency omnidirectional radio range; (*b*) distance measuring equipment; (*c*) surveillance radar; (*d*) precision approach radar; (*e*) instrument landing

Note.—Written comments are invited for publication; the last discussion should be submitted by May, 1, 1952.

[1] Chf., Airports Div., CAA Region V, Kansas City, Mo.

[2] *SC–31 Report*, by Special Committee 31 of the Radio Technical Committee for Aeronautics, Washington, D. C., May 12, 1948.

[3] "Air Traffic Control and the National Security," Report of the Operational Policy Group, Air Coordinating Committee, Washington, D. C., December, 1950.

system; and (*f*) high intensity approach lights. The purpose of these navigational and landing aids is to accommodate a greatly increased number of aircraft in the flight lanes and to guide them more quickly to safe landings at their destination. The federal government cannot undertake the entire job alone, and each local community must be in partnership with the government in the effort to handle a constantly increasing volume of air traffic.

Most of the major air transport centers of the United States have already developed their airports, and only a few new major airports are going to be developed in the foreseeable future. In most of our major cities it is logical, therefore, to assume that activity will continue at the existing airport. Four main reasons for this assumption are: (1) The investment in the existing facility must be considered; (2) the normal resistance to relocation must be overcome; (3) the growth of most major cities tends to force the location of a new airport to open country, generally an excessive distance from the center of the city; and (4) the element of cost in which even the first stage of developing a new airport can represent a rather staggering amount of money. Therefore, this paper considers only redesign as opposed to new development.

Airport Capacity

Effect of Electronic Development.—The electronic developments of the transition period, as previously mentioned, will do much to make all-weather flying a reality. They will permit a very high percentage factor of flight operations to be achieved. Actually, on major airports, it is logical to think of the capacity of the airport as the number of aircraft that can be handled during restrictive weather. This concept follows from the fact that the major portion of stable traffic on the average airport is that generated by scheduled air carriers plus those nonscheduled civil, cargo, and military aircraft that regularly fly, regardless of the weather. Thus, any increase in airport capacity for this segment of the aviation industry must be measured in terms of capacity during instrument weather. The fact has affected the thinking of the industry regarding airport layouts, the spacing of parallel runways, the design of taxiway systems, and the parking of aircraft at loading areas. Also, one point is becoming more and more obvious—the ability to use electronic developments to guide aircraft to the threshold of the runway results in a capacity that exceeds the acceptance rate of most airports. In other words, it appears practicable to bring in aircraft at the rate of 1 every 1.5 min or at a steady rate of 40 per hr.

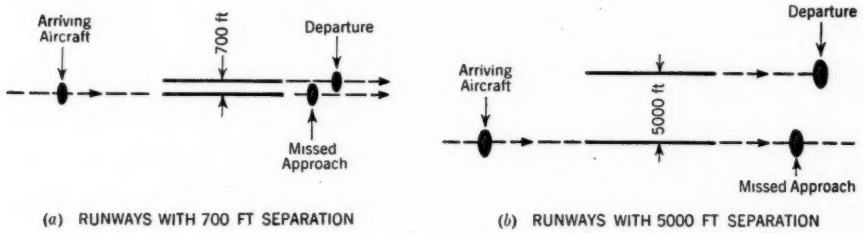
Factors Affecting Capacity.—There are few airports that can accept aircraft at the rate of 40 per hr, because of two factors:

a. Inability of planes to clear the runway in sufficient time; and
b. Lack of adequate ramp space for parking.

Before attempting to solve the problem, it should be thoroughly understood. The landing of aircraft 1.5 min apart, during weather of restricted visibility, is really a rapid rate when considering that the pilot does not have visual contact with the ground and the airport traffic controller does not have visual contact with the aircraft. In order to maintain this rate the landing aircraft must, of

necessity, clear the runway at the earliest possible instant. This requires that the runway must have taxiways at frequent intervals throughout its length so that aircraft can get off the runway as soon as the speed has been reduced sufficiently to permit a turn to be executed. If the taxiways lead from the runway at an angle of 30° or 45°, naturally, the aircraft can turn at a higher rate of speed than if a 90° or more acute turn must be made.

To land aircraft at the rate of 40 per hr means that one runway must be restricted exclusively to landings. A second runway must be available for take-off, permitting aircraft to leave the airport at the same rate of 40 per hr. Under instrument conditions, it is doubtful that parallel runways can be used simultaneously unless they are separated by a minimum distance of 3,000 to 5,000 ft (Fig. 1(*a*)). A simultaneous departure on one parallel runway and a missed approach on the corresponding landing runway would put both aircraft in the air very close together along the projected center lines of the



(*a*) RUNWAYS WITH 700 FT SEPARATION (*b*) RUNWAYS WITH 5000 FT SEPARATION

FIG. 1.—REQUIRED SEPARATION FOR PARALLEL RUNWAYS

parallel runways. The horizontal separation would be inadequate for safe operations. Fig. 1(*b*) shows the condition of parallel runways having adequate runway separation. The use of intersecting runways, one for landing and one for take-off, is preferable to parallel runways without adequate clearance, inasmuch as the projected center lines of the runways diverge, resulting in a constantly increasing separation.

Coupled with the runway and taxiway requirements is the problem of parking aircraft after they have landed. It is obvious that aircraft cannot be landed at the rate of 40 per hr unless the available parking areas will provide adequate accommodations for them. The Airport Operators Council has conducted surveys in this regard, and the CAA is attempting to establish basic criteria for determining the requirements for gate positions on loading ramps. Only a few airports in the country have loading aprons adequate to take care of scheduled arrivals at the rate of 40 per hr.

FEATURES OF DESIGN

Several basic requirements must be met if an airport is to achieve maximum efficiency when handling near-capacity volume of traffic. These requirements may be listed as:

1. All airports in a community should be located so their respective instrument traffic patterns do not overlap or conflict with each other;

2. Adjacent airports served by instrument approach aids should be located so that their respective instrument traffic patterns for both arriving and departing aircraft do not overlap or conflict with each other;

3. Landing, taxi, and take-off must be considered as independent operations, and allowance must be made for their accomplishment without mutual interference;

4. Where practicable, the runways should be separated so that simultaneous use may be effected without conflict of traffic patterns. This will greatly increase the capacity and permit more direct approaches and departures and thus save aircraft time and reduce traffic congestion;

5. The airport should be so designed that the air traffic control tower can achieve flexibility in the choice of take-off sequence without regard to the sequence of taxiing from the ramp to the take-off runway;

6. Taxiways should be located at various points along the runway to permit landing aircraft to turn off the runway as quickly as possible to clear it for other aircraft and to provide minimum taxi distances to the service or ramp area on completion of the landing roll;

7. Taxiing aircraft should be able to pass other aircraft that are parked or holding on loading aprons on near runway entrances;

8. Taxi exits should be marked in such a manner that the pilot can anticipate the turnoff point in sufficient time to enter the taxi exit easily under day or night conditions; and

9. The control tower must provide excellent visibility of the entire airport area used by aircraft and all the approach and departure areas.

These requirements can easily be met in a new airport design. It is much more difficult, but generally possible, to incorporate the essential features into existing airports, with a minimum of compromise, assuming, of course, that the airports are properly located and susceptible of modification.

Redesign of Lambert-St. Louis Municipal Airport

The writer recently participated in a study of the master plan of Lambert-St. Louis Municipal Airport. Lambert Field is one of the major airports in the country. It was initially developed in the early 1920's and has been expanded from time to time as changing aeronautical conditions required. The airport has a complete variety of traffic including flight training, charter work, executive transport, military, cargo, and scheduled airlines. There is an adjacent aircraft factory that manufactures jet planes. Therefore, the airport operates at high capacity during good weather conditions. This requirement for capacity drops off considerably during restricted visibility weather.

Fig. 2 shows the master plan of Lambert Field, developed in 1944 and prepared on the basis of the best thinking current at that time. The old portion of the field is toward the western side. By 1950 a major grading project was in progress on the eastern portion of the airport.

This master plan was based on the time-proved concept of a three-runway layout with one runway usable at a time, depending upon wind direction. Provision was made for future parallel runways when traffic density required.

There is nothing wrong with such a concept, except that the expense of parallel runways is considerable and unnecessary if the airport can be designed so that all runways can bear traffic simultaneously.

Fig. 2. also shows suggested revisions to the master plan. The changes represent adaptations that conform with advanced thinking in airport design

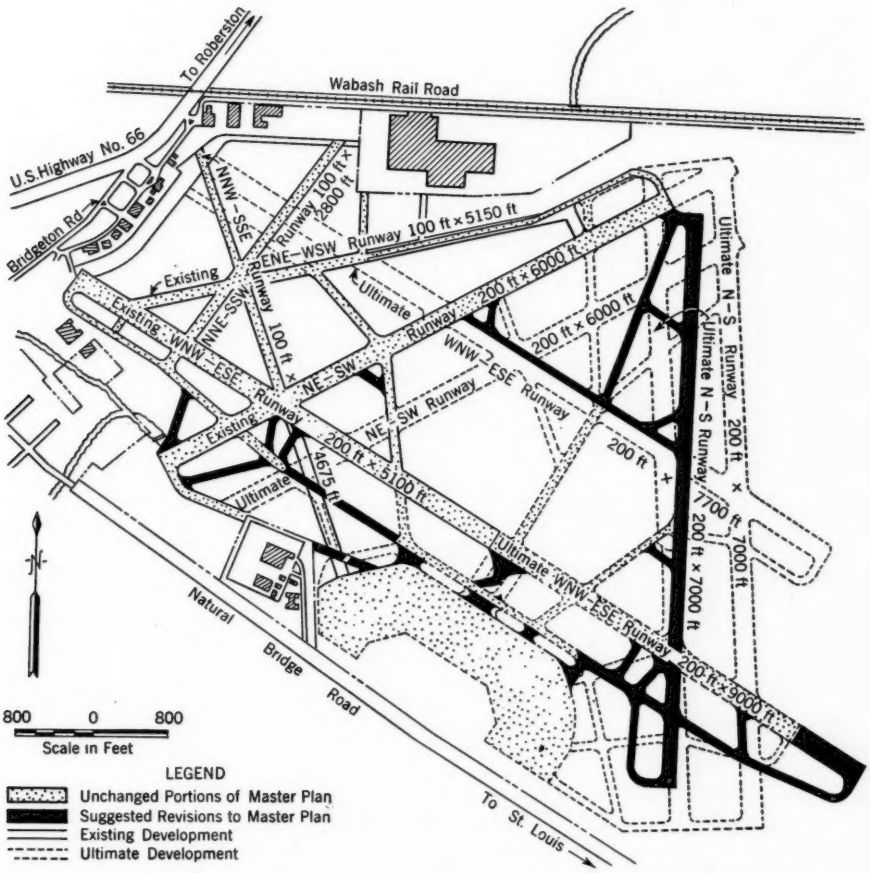


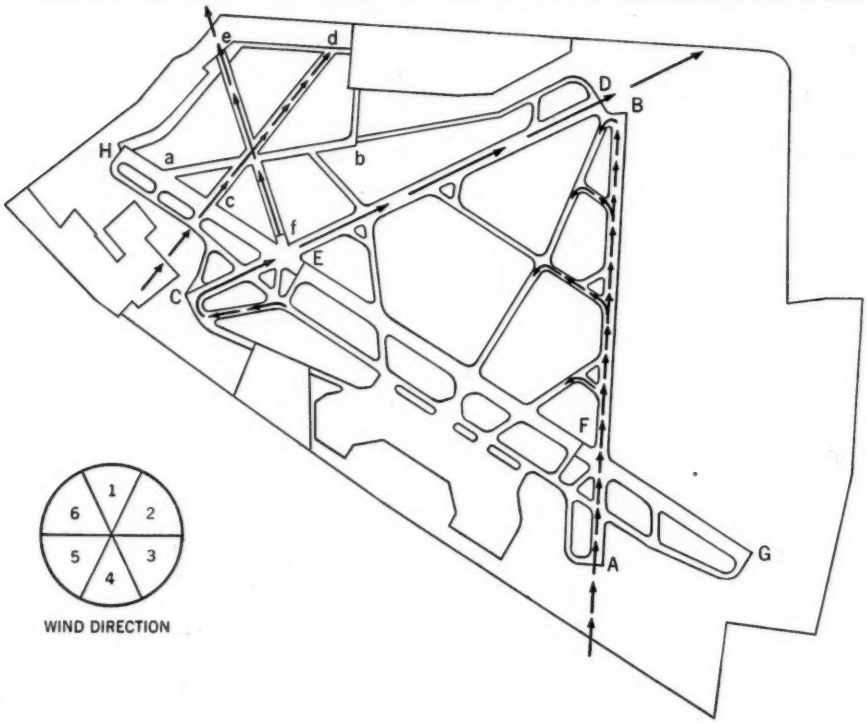
FIG. 2.—LAMBERT-ST. LOUIS MUNICIPAL AIRPORT RECOMMENDATIONS FOR DEVELOPMENT (1950)

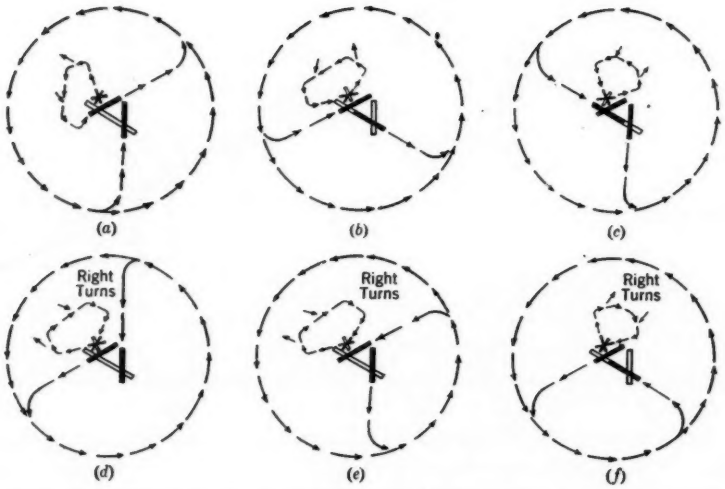
and give the airport its maximum traffic capacity without providing parallel runways. The suggested revisions include:

(*a*) An increase in the ultimate length of northwest-southwest runway from 9,000 ft to 9,800 ft to provide a minimum of 7,000 ft of usable runway in either direction and still permit other runways to operate;

(*b*) Relocation of the proposed north-south runway by rotating it about 5° to the east, thus eliminating the intersection of the north-south and northeast-est runways and permitting their simultaneous use;

TABLE 1.—TRAFFIC PATTERNS AT LAMBERT-ST. LOUIS MUNICIPAL AIRPORT





Wind direction	Landing Runway		Take-off Runway		Area pattern	Percentage of time applicable[a]
	Light aircraft	Other aircraft	Light aircraft	Other aircraft		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	cd	AB	fe	CD	a	10.2
2	ab	CD	cd	EG	b	9.9
3	ef	HF	ab	BA	c	12.9
4	dc	BA	ba	DC	d	16.6
5	dc	DC	ba	BA	e	17.6
6	ba	GE	fe	DC	f	19.8

[a] Not including calm wind periods.

(*c*) Revision of the taxiway system; and
(*d*) Provision for bleed-off taxiways.

The objective of the suggested revisions is to increase the potential capacity of the airport by making two major runways traffic-bearing (one for take-off and one for landing) simultaneously.

Table 1 indicates the traffic patterns that will develop peak capacity under various wind conditions. In each case the runway must nearly alined with the wind is used for landing, and a runway quartering into the wind is used for take-off. Both can be used simultaneously. Provision is also made for light aircraft on the west side of the field, using existing runways. These runways intersect but permit nonconflicting traffic patterns, and under proper control they offer greater capacity than a single runway. Vicinity patterns show the lack of conflict between light and heavy aircraft patterns.

The resulting capacity approximates that of parallel runways. The potential saving of approximately $3,000,000 probably influence the city officials of St. Louis, who received this study enthusiastically.

These patterns are developed for contact flying conditions. Instrument use of the airport would, of course, be restricted to the major runway system. At the present time the northeast-southwest runway is the instrument runway. If this continues to be the instrument runway, it can be used exclusively for landing, with take-offs from the western portion of the northwest-southeast runway that does not interfere with the use of the instrument landing runway.

If the northwest-southeast runway becomes the instrument landing runway (with approach from the southeast the northeast-southwest runway can be used for simultaneous take-off, or if the approach is from the northwest, the north-south run can be used for take-off.

The ultimate apron provides thirty parking positions for aircraft, which appears to be sufficient to permit capacity operation of the airport.

Studies indicate that the capacity of the airport for both instrument and contact weather will be sufficient to satisfy the needs of St. Louis for at least the foreseeable future.

Conclusion

In the case of St. Louis, it was possible, by relatively minor revision of the master plan, to eliminate the intersection of runways. The test of a good master plan is "its ability to accommodate itself to changes and advances in technological developments."[4] On this basis the St. Louis master plan of 1944 was a good one. No master plan for an airport can be a static one, for the aviation industry sees frequent and far-reaching technological changes.

Fig. 3 shows the layout of Stapleton Airfield at Denver, Colo. Here the east-west runway is to be the instrument runway with approach from the east. For several reasons it is not possible to expand the airport sufficiently to permit any two runways to be nonintersecting. For capacity operation, however, aircraft can take off to the north, on a runway that intersects the east-west runway near its western end. Properly controlled, the traffic

[4] "Master Plan-Chicago International Airport," by Ralph H. Burke, Chicago, November, 1950.

capacity could approach that of parallel or nonintersecting runways, provided that the capacities of the taxiway system and parking ramp are increased.

Further analysis of various layouts would indicate that properly designed airports are generally susceptible of redesign to meet changing conditions.

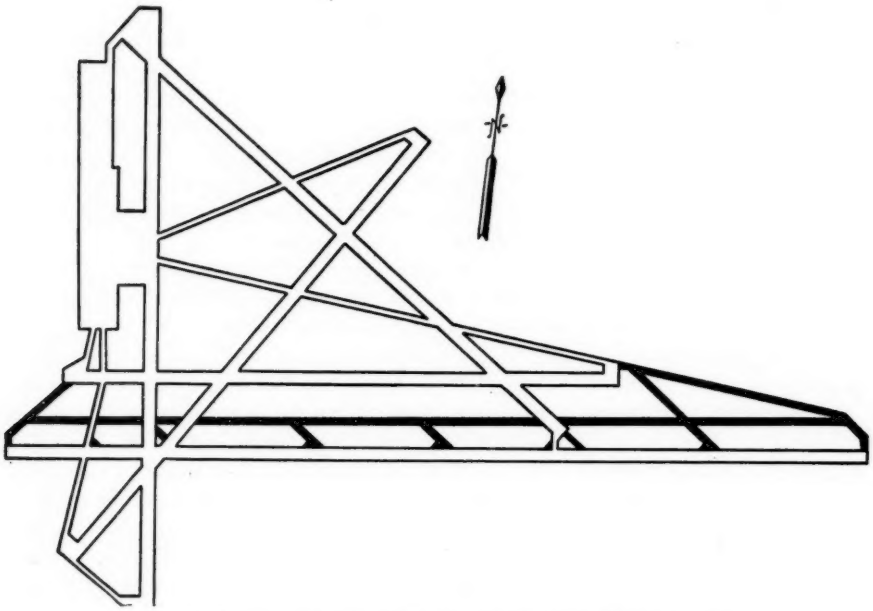


FIG. 3.—STAPLETON AIRFIELD—RECOMMENDATIONS FOR DEVELOPMENT

At first glance, the almost daily changes in the industry present a hopeless problem to the airport engineer, but the advancement that the aviation industry has made is adequate testimony to the ability of engineers to meet and solve these problems.

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